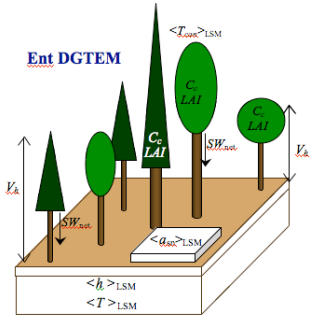
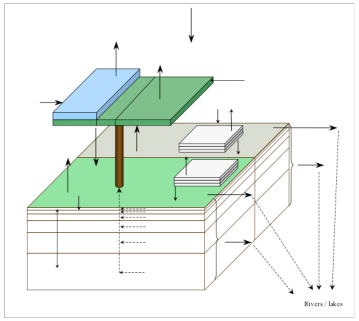
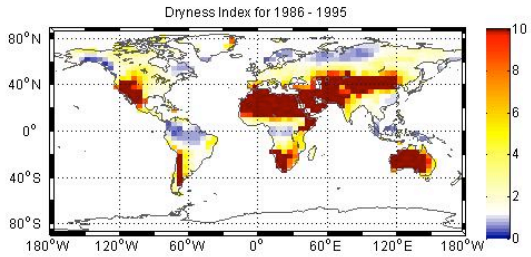
# Towards the Rebirth of the NASA GISS Land (Surface) Model: Challenges and Opportunities



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*May 6, 2009*
*NASA GISS Lunch Seminar*

# Collaborators

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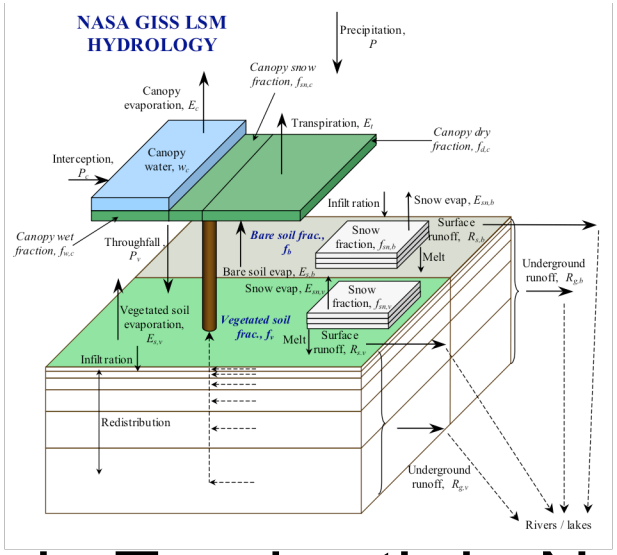
- Nancy Y. Kiang
- Igor Aleinov

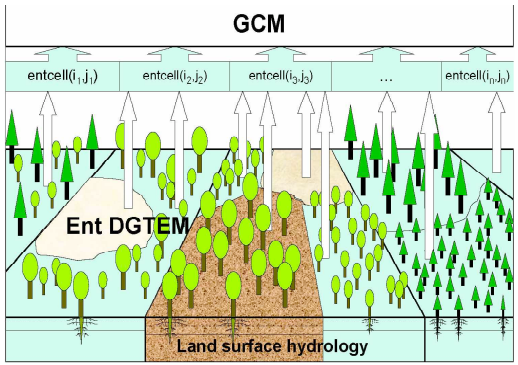
*NASA Goddard Space Flight Center*

- Randy Koster

# Motivation

- Coupling the Ent Dynamic Global Terrestrial Ecosystem model with the GISS Land Model



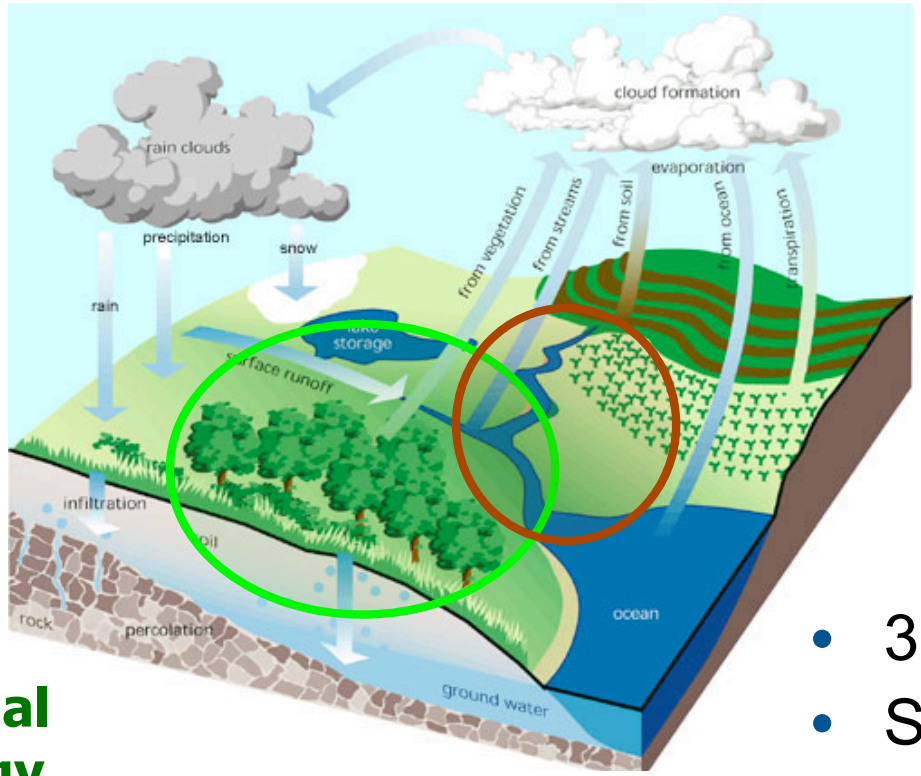




- Kevin Trenberth in Nov. 2008 @ GISS 3rd Floor: doesn't trust the predictions of the GISS land model
  - Reduce confidence in modeling community
  - Marginalization of the GISS land model

# Outline

- Introduction
- Existing GISS Land Model
  - Opportunities for improvement
- Current model development
  - Ecosystem-scale analyses
  - Global-scale analyses
- Development framework


# Hydrologic Land Processes




**Terrestrial hydrology**

**Fluvial hydrology**

- 3-D land surface
- Significant spatial hetero-geneity soil, vegetation, and topography
  - Surface runoff
  - Ecosystem dynamics

# Importance of land model

- Water cycle components interact with and affect:
  - Carbon (and nitrogen) cycle
  - Fire dynamics
  - Dust and trace gas emissions
  - Vegetation dynamics
- Partitions water & energy into storage reservoirs.
- Controls the release of water vapor and energy to the atmosphere.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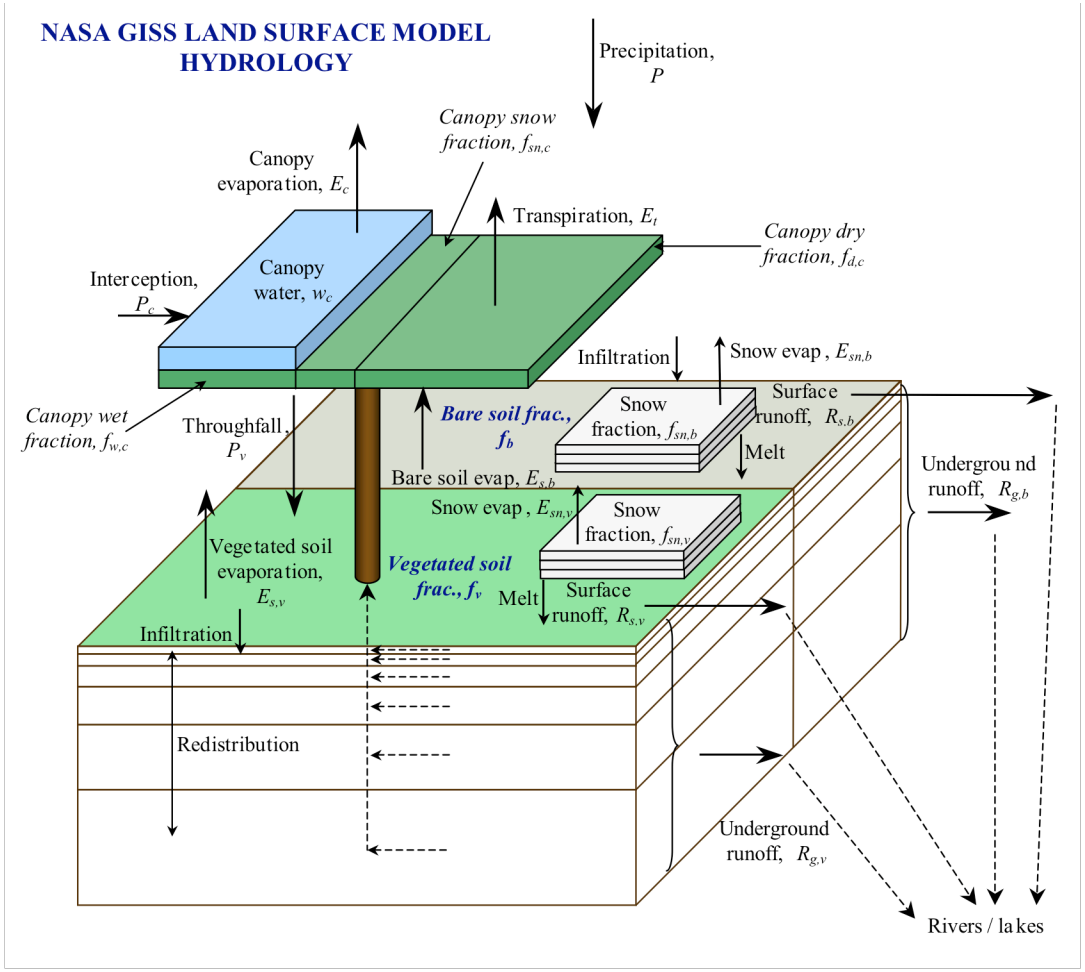
# Current NASA GISS Land Model




- Divided into bare-soil and vegetated sections, which are conceptualized as interspersed
- A single water & energy balance for all vegetation (patches) within a grid cell
- Soil column is 3.5 m thick and 6 layers everywhere
- Explicit solution of heat & water transport in the soil column

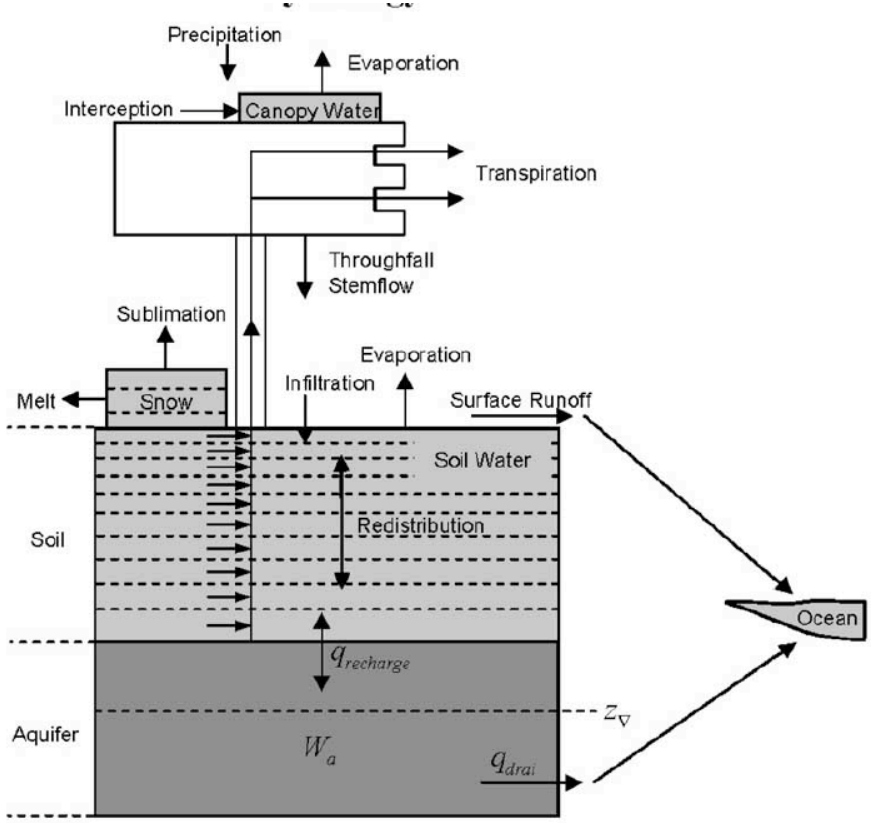
# Options for Improvement

- Continue with a one-dimensional representation (e.g. NCAR) $T_{1D}, R_{1D}$
  - Heterogeneity (e.g. soil, topography) through statistical approaches
- Catchment-based model of GSFC (Koster et al. 2002) $T_{GSFC} > T_{1D}$ $R_{GSFC} > R_{1D}$
- New approach to capture the heterogeneity of the land's soil, vegetation, and topography $T_{INNOVATIVE} > T_{GSFC}$ $R_{INNOVATIVE} > R_{GSFC}$


# 1D example: Community Land Model

Oleson et al (2008):

- Improved canopy integration scheme (Ent DGTEM)
- Scaling of canopy interception
- TOPMODEL-based model for surface and subsurface runoff
- Groundwater model for determining water table depth
- New frozen soil scheme
- New surface data sets and parameterizations (new land-cover maps, LAI, SAI, and soil color based on MODIS products) (Lawrence and Chase, 2007)



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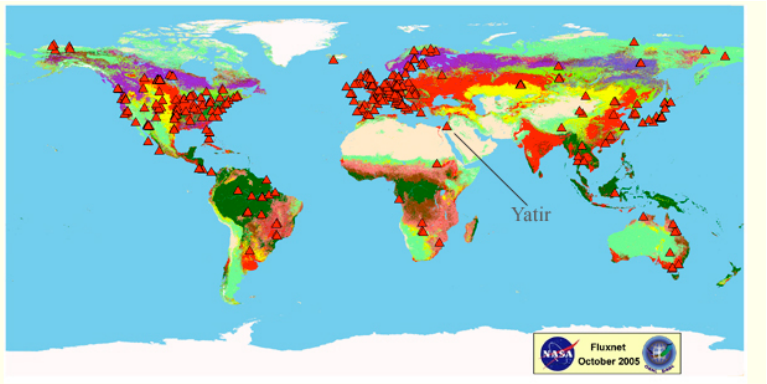
# Framework

- Land model must be tested offline!!
- GISS land model needed to separated from the GISS GCM
- Setup needed to test offline at 2 spatial scales
  - Ecosystem scale
  - Global scale
- FLUXNET comparisons
- Global meteorological reanalysis datasets
  - 1986-1995 data from the GSWP2
  - 50+ years data from Princeton group



# Current modifications

- Poor simulation of veg. biogeography (Oleson, 2008)
  - Global-scale: forest cover is underestimated in favor of grasses due to dry soil
  - Amazon: less broadleaf evergreen & more deciduous trees
- Problems
  - Inaccurate evapotranspiration partitioning (transpiration, soil evaporation, canopy evaporation)
  - Amazon soil moisture

| | GSWP2 Mean of models (Dirmeyer et al., 2005) | Choudhury et al. 1998 | Old NCAR forced w/obs |
|---|---|---|---|
| Transpiration | 48% | 52% | 13% |
| Soil Evap. | 36% | 28% | 44% |
| Canopy Evap. | 16% | 20% | 43% |

# Vegetation and evapotranspiration

- Poor simulation of veg. biogeography (Oleson, 2008)
  - Global-scale: forest cover is underestimated in favor of grasses due to dry soil
  - Amazon: less broadleaf evergreen & more deciduous trees
- Problems: inaccurate ET partitioning, Amazon soil moisture

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# Modifications to GISS LM hydrology

- Evaporation from vegetated soil - previously none
  - canopy sheltering effects: modify atmospheric transfer coefficient based on leaf area index
- Temporal correlation in storm position (Koster and Suarez, 1996)
  - Increase precipitation throughfall
  - reduces wet canopy fraction
- Scheme to account for wet-layer effects (i.e. stomatal blocking) on water & carbon fluxes
  - Depends on plant functional type

# Morgan Monroe State Forest

- Broadleaf deciduous forest in Indiana
- Temperate continental climate:
  - mean annual temp. ≈ 12.4 °C,
  - mean annual precipitation ≈ 1094 mm

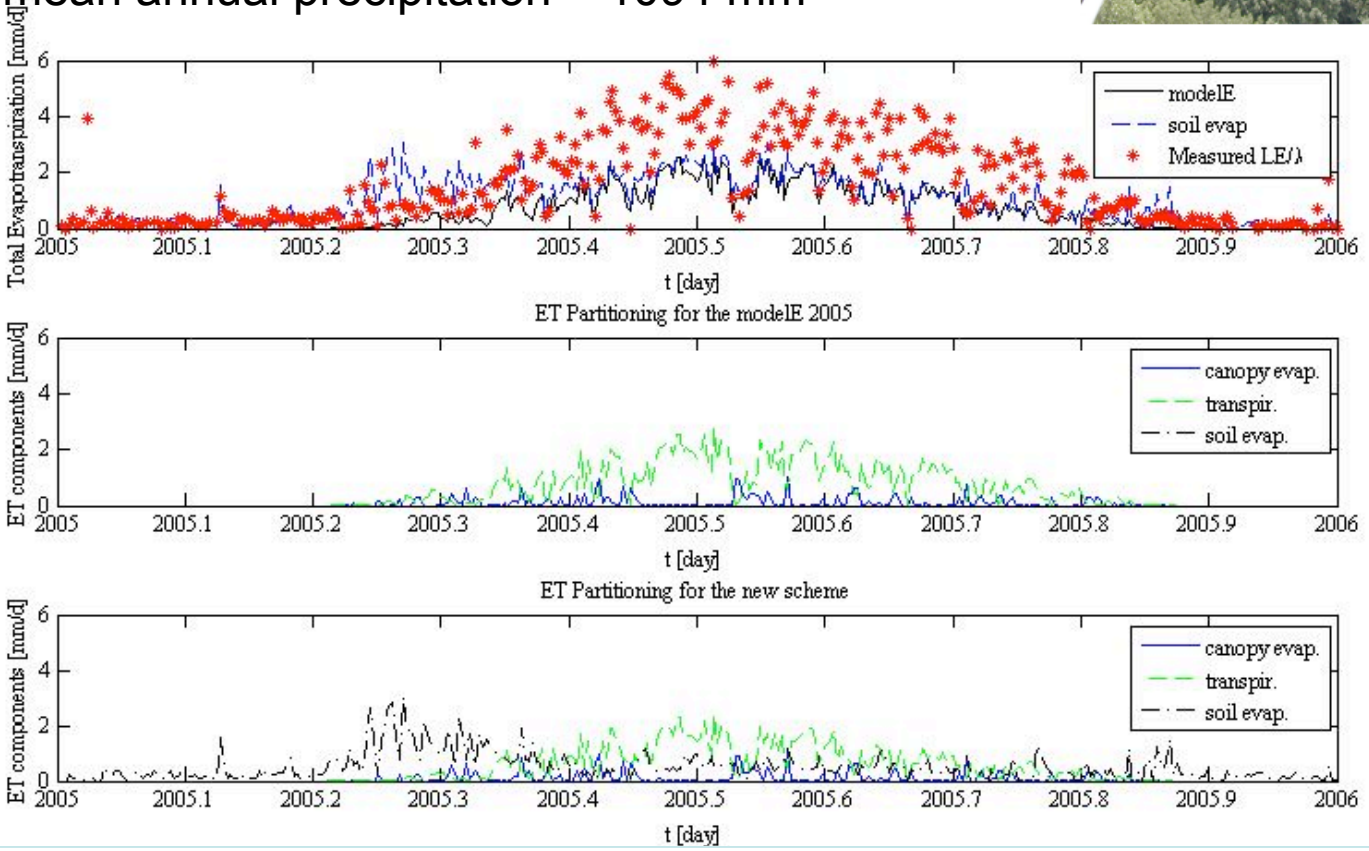
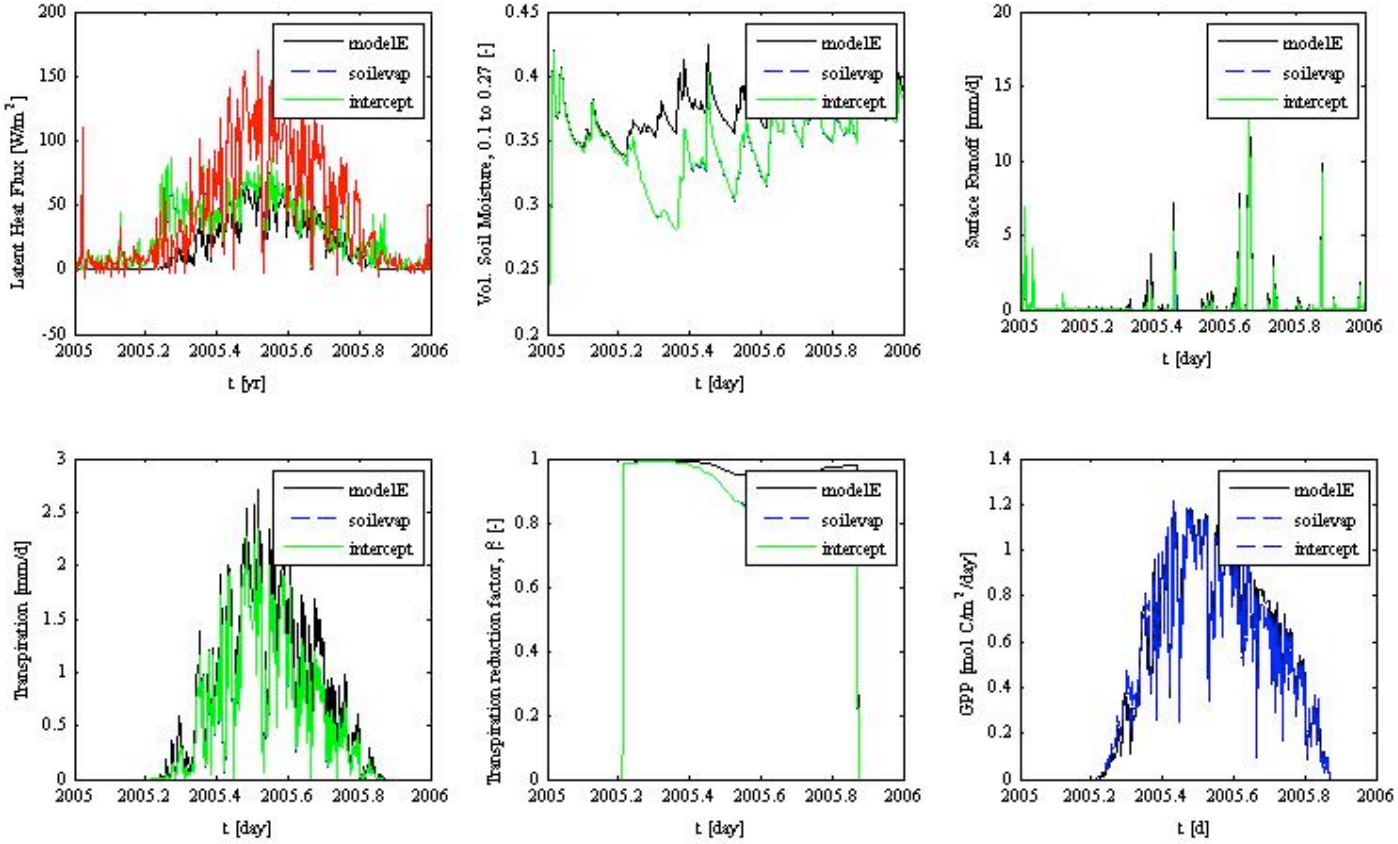



Image: http://public.ornl.gov/ameriflux/Site_Info/Images/20010608W.jpg

# MMSF - 2005




- Total evapotranspiration is underestimated during growing season
- Different schemes have minimal effect on productivity

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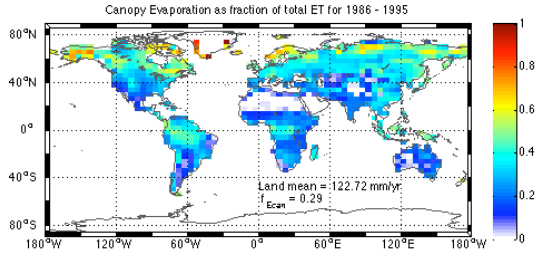
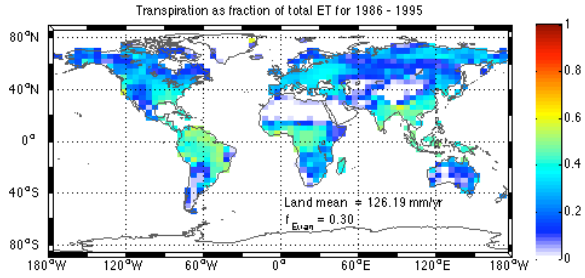
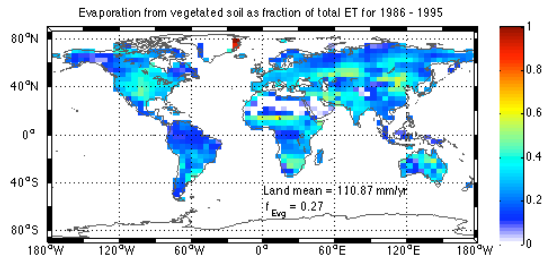
# Evapotranspiration partitioning




Original scheme

29%

30%

27%

| | GSWP2 Mean of models (Dirmeyer et al., 2005) |
|---|---|
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| Soil Evap. | 36% |
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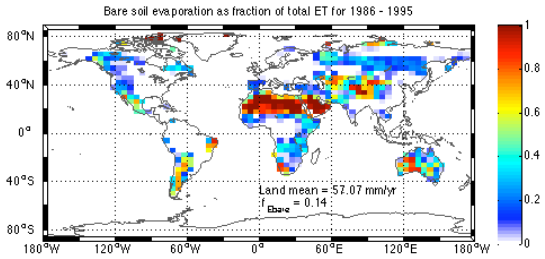
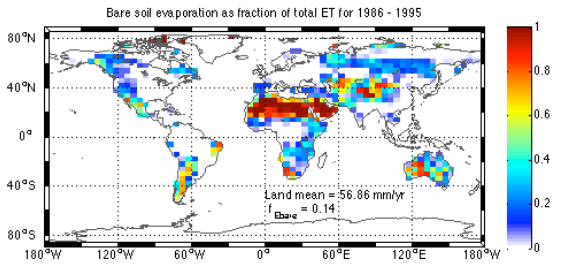
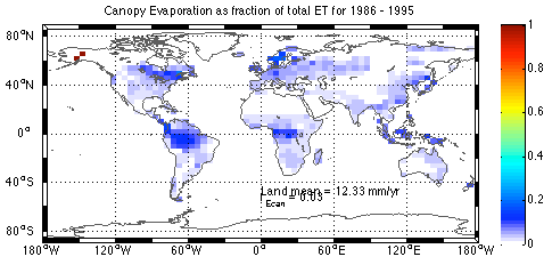
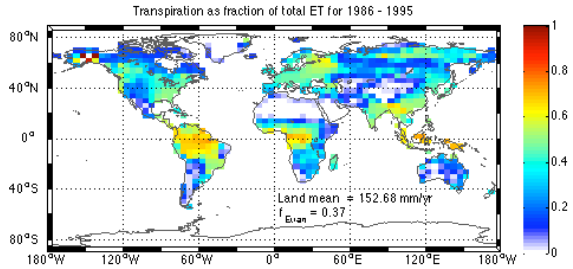
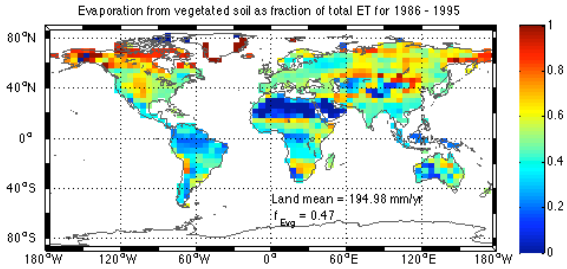



14%




Modified scheme

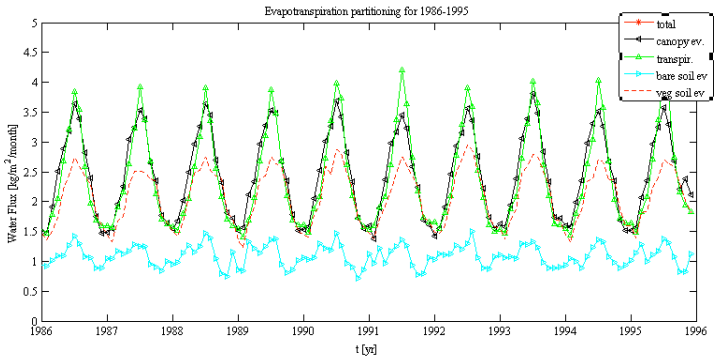
3%

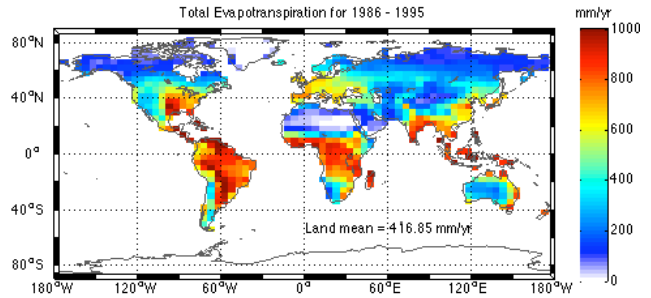
37%

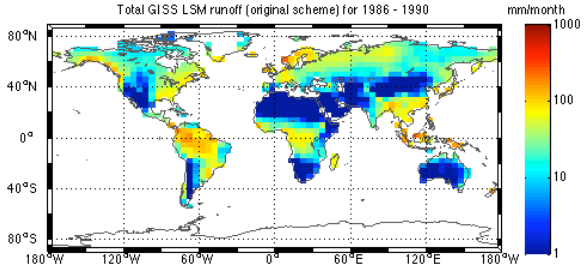
47%

# Hydrologic components

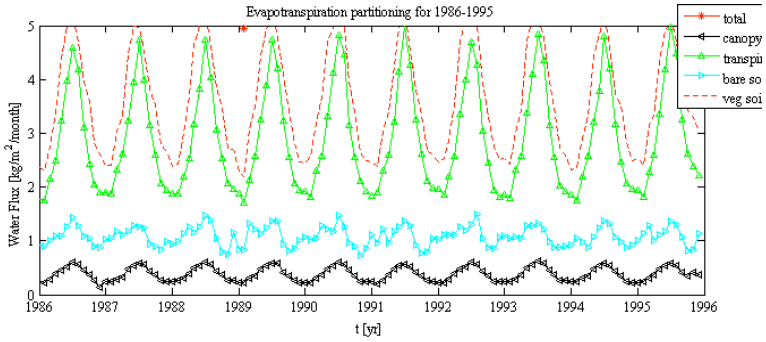
## Original Scheme

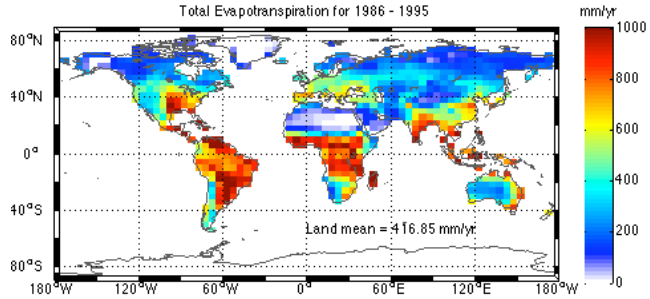


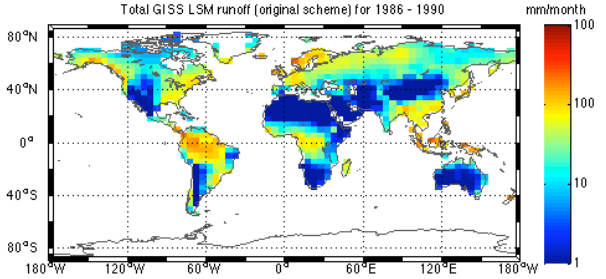




## Modified Scheme




Total ET:
No Change

Runoff:
No change

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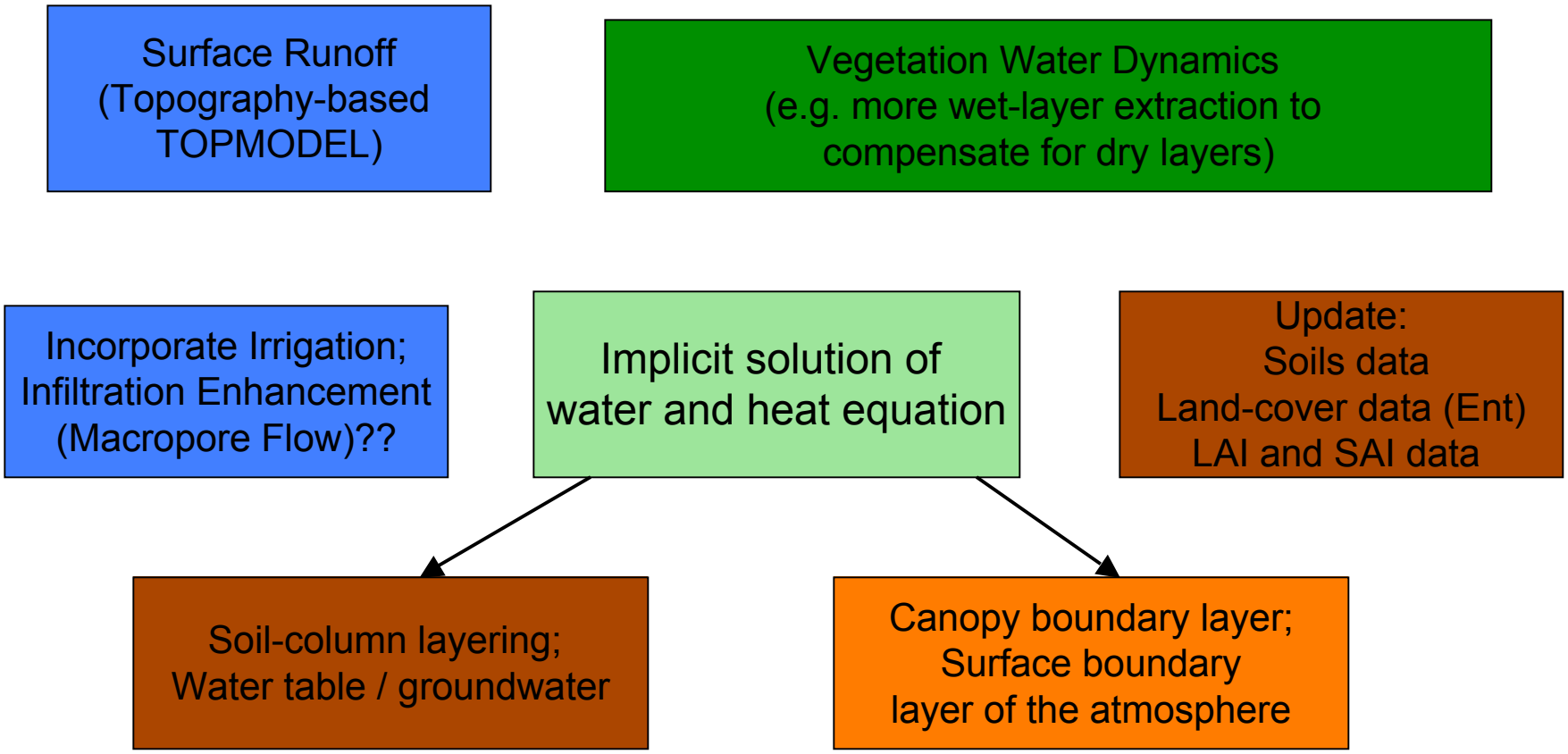
# Development Framework: 1D model

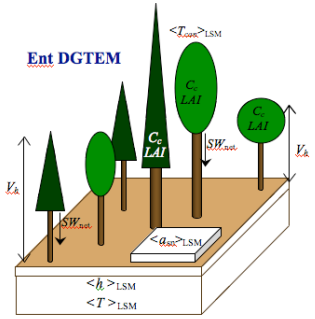


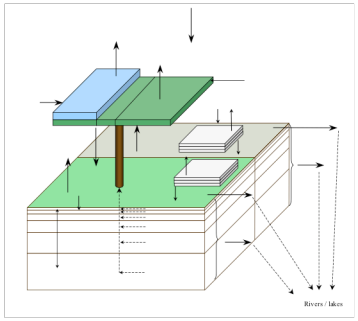
# Return on Investment

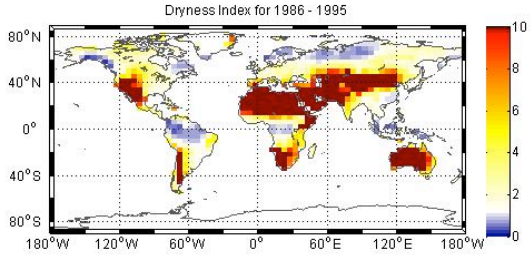
$$ROI = \frac{\text{Gain from Investment-Cost of Investment}}{\text{Cost of Investment}}$$

- Cost of Investment
  - 1 or 2 additional researchers
- Gain from Investment
  - Increased recognition in the modeling community
  - Postdoctoral researchers
  - Better runoff predictions
  - Better carbon cycle
  - Better ecosystem dynamics
  - Better climate predictions
  - Potential to create a new, innovation land model

# Questions ?


Ent DGTEM
$<T_{can}>_{LSM}$
$C_v$ LAI
$C_v$ LAI
$C_v$ LAI
$SW_{net}$
$SW_{net}$
$V_h$
$V_h$
$<\alpha_{soil}>_{LSM}$
$<h>_{LSM}$
$<T>_{LSM}$




Dryness Index for 1986 - 1995
80°N
40°N
0°
40°S
80°S
180°W
120°W
60°W
0°
60°E
120°E
180°W
10
8
6
4
2
0